

Method and system for locating a terminal in a wireless telecommunications network, computer program product therefor

5 FIELD OF THE INVENTION

The present invention deals with a method and a system for locating a terminal in a local telecommunications network of the wireless type, in addition to a wireless
10 telecommunications network comprising such system, and a corresponding computer program product.

The local wireless telecommunications networks are meant, depending on what is included, for example, in IEEE 802.11
15 Standard and commonly known, as networks optimized by geographic areas with limited sizes, such as individual palaces for offices, warehouses or set of buildings and owned used and managed, in general, by a single organization.

The term local wireless telecommunications networks also
20 covers networks for airports, harbors, railway stations and whichever is similar to such type of environment.

The term local wireless telecommunications networks also covers networks for very limited areas as regards sizes, such as, for example, small offices, individual laboratories and
25 home environments.

In the following description, the term local wireless telecommunications networks will cover such type of definition.

30 A local wireless telecommunication networks, such as, for example a WLAN, is composed of a plurality of base stations (Access Points) for user access to the network, distributed on a circumscribed area. All Access Points have

omnidirectional or directional antennas through which they realize a cellular coverage of the area itself. The Access Points are then generally connected to a wired network (wired LAN) through which the users can use several services.

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Every user is equipped with a terminal, for example a portable or palmtop computer, for using the services. Such terminals are equipped with a wireless communication apparatus (WLAN apparatus) integrated in the terminal or not, such as for example a PCMCIA card, a PCI adapter, etc. Communications between Access Points and terminal WLAN apparata exploit the radio medium and occur through standard protocols, such as for example the IEEE 802.11 or HIPERLAN protocol, or proprietary ones.

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PRIOR ART

Many systems and methods for locating WLAN terminals are known in the art. In particular, there are systems and methods that allow performing the WLAN terminals location in a network that is entirely composed of common apparata (Access Points and WLAN apparata), namely systems and methods that do not require modifications to network apparata and/or terminals in order to introduce accessory functionalities required by the location process.

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The methods (and systems) known in literature are essentially of two types:

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Methods (and systems) that required the a priori knowledge of measured signatures.

Signatures are maps that associate to predetermined spatial
5 positions belonging to the network coverage area one or more
parameters measured by the signal transmitted by the Access
Points.

An example of measured signature can be obtained by
10 arranging, for example, measuring instruments in points whose
position is known a priori and collecting for each one of
them, for example, the received powers related to signals
transmitted by various Access Points and/or received
signal/noise ratio values and/or simply recording the serving
15 Access Point and/or the received Access Points.

A method for locating a WLAN terminal based on signatures
collection is disclosed in WO-A-02-054813. Such method allows
performing an estimation of the position of a WLAN terminal
20 without the need of knowing a priori both the network
infrastructure and the characteristics of the environment in
which the network itself is deployed. The location process is
divided into two steps: system calibration step, in which
signatures are collected, and a step in which terminal
25 location is performed.

During calibration, for each one of the points in the affected
area (calibration points) a set of data (signatures) is
determined, that comprise the point position and the measured
30 value in such point of one or more parameters (for example
power or error rate) of the received signal, for each one of
the available channels in the system. Signatures are used to
realize a statistic model of the parameter or the set of

parameters with respect to the position.

The second step is the terminal location real and proper, that occurs after that this one has performed a measure of the same parameters for each one of the channels, depending
5 on the comparison between the results of such measures and the statistic model.

Methods of this type can be very accurate. However, they
10 require a setup (configuration) step that consists in a rather big collection of signatures. In fact, it is necessary to perform a measure of the chosen parameters, further specifying for each point, its geographic coordinates, in the area within which the location service has to be made
15 available.

In an indoor environment, it can be problematic and costly to locate the coordinates for signatures collection points; moreover, this configuration step must be performed again
20 when any network modification is carried out (insertion, removal or movement of an Access Point, modification of a frequency or of one of its radio-electric parameters, etc.) or in the environment (furniture movements, etc.).

25 Finally, these methods, in order to be able to fully exploit their potentiality, require that, when locating, the terminal whose position must be located is able to carry out a measure of signal parameters transmitted by the Access Points. There are several cases in which the terminal equipped with WLAN
30 terminal is not able to perform such measures.

Methods (and systems) that require the knowledge a priori of

the Access Point positions.

Within such class, the methods (and systems) are divided by type of information required by the system during the location process, and namely:

a. methods and systems that perform a terminal location depending on the Access Point to which the terminal itself is connected (serving Access Point);

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b. methods and systems that perform a terminal location depending on the powers of signals received from a terminal and transmitted from the Access Points that is sees.

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An example of a system in which the location is performed only depending on the Access Point to which the terminal is connected is disclosed in EP-A-1 180 873. This document discloses, in particular, a system for distributing information services to users of a WLAN, arranged to provide specific information about a terminal position by identifying the Access Point from which the user performs his own service requests and relating the position of such Access Point in the network infrastructure with the position of a site belonging to the network coverage area whose characteristics are object of the request.

An example of a system in which instead the location is performed depending on measures carried out by the terminal of parameters related to received Access Points is disclosed in EP-A-1 111 951.

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In such document it is provided that a terminal performs

power (RSS, Radio Signal Strength) measures and/or BER (Bit Error Rate) measures on the signal received by it and transmitted by at least three (preferably more) Access Points, and that it sends such measures to a server which,
5 having a map available with the position of the network infrastructure Access Points, estimates the WLAN terminal position through a triangulation mechanism.

This method assumes that all Access Points transmit with the
10 same power, have omnidirectional antennas and that the interference level is homogeneous on the whole area; these assumptions often are not verified since in a WLAN network of a common type the Access Points can transmit at different powers and the used antennas can be directional and not
15 omnidirectional.

Methods of this type have the disadvantage to be able to locate a terminal with an error of the same magnitude error and size of the cells. In many applications and services,
20 this uncertainty makes the system unusable, both because often the cells are too big, and because the application or service requires a higher accuracy than the one that can be obtained with the examined method.

The Applicant has detected that, within the known methods and
25 systems, no location tools are provided that can be flexibly adapted to the characteristics of used terminals and the type of installed local network.

SUMMARY OF THE INVENTION

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Object of the present invention is realizing a method and a system for locating terminals of a local wireless telecommunications network that do not depend on a pre-

established set of configuration data, but that allow a relatively accurate location of a terminal by flexibly adapting themselves to those information that the system has available, namely the set of configuration data, the terminal characteristics and the desired location accuracy.

According to the present invention such object is obtained due to a method and a system for locating a terminal in a local wireless telecommunications network having the characteristics contained in the independent Claims.

Further objects of the invention are a local wireless telecommunications network and a processing program or group of programs as claimed.

Synthetically, the present invention is based on the principle of selecting one of a plurality of location procedures or techniques of a terminal in a local wireless telecommunications network depending on information which the locating system has or can have available (namely the set of system configuration data, information or measures that the terminal or network can provide and the desired location accuracy).

According to one among the various characteristics of the present invention, the locating request of a terminal operates flexibly; in fact, to satisfy the necessary requirements for the locating request, a predefined and rigid system configuration is not necessary, nor the type of mobile terminal to be used is a constraint.

Depending on available configuration information or configuration economy criteria, and the type of terminal to which the location has to be provided, the method and system

object of the invention allow choosing the best combination of information to obtain the best possible accuracy or satisfy a minimum desired accuracy threshold, respectively.

5 The method has the following characteristics:

- it can be used to locate any terminal (in terms of combination of terminal, wireless communication apparatus and operating system), independently from the measures that the terminal itself is able to provide;
- 10 - in a starting configuration step, depending on the location accuracy required by the users and depending on used terminals, it specifies to the system user which information (in terms of Access Points position, their electromagnetic characteristics, signatures etc.) it is necessary to provide;
- 15 - if the system user has available only a subsystem of such information, the system is anyway able to guarantee the location service with the maximum possible degree of accuracy.

20 The present invention provides, among others, a flexible solution for locating WLAN terminals that is adapted to any combination of information being present or available in the affected WLAN.

25 Procedures are further provided for locating WLAN terminals under particular combinations of available configuration information and measures by the terminal that represent valid compromises in terms of location accuracy and configuration complexity.

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DETAILED DESCRIPTION OF THE FIGURES

Further advantages and characteristics of the present

invention will appear from the following detailed description, provided as a non-limiting example with reference to the enclosed drawings, in which:

figure 1 is a schematic representation of a WLAN
5 network;

figure 2 shows a table of procedures for locating a WLAN terminal depending on necessary information for system configuration and information provided from terminals to system during location; and

10 figures 3 and 4 show a portion of local network (in which three Access Points are shown) and related location areas for a terminal according to procedures object of the invention.

15 DETAILED DESCRIPTION OF THE INVENTION

The method and system for locating terminals in a wireless telecommunications network described herein below specifically refer to a network of the WLAN type, as recalled
20 in the introductory part of this description.

The invention, however, is applied to any wireless network of the local type.

25 For realising the invention, necessary information for locating a terminal are divided into two categories: respectively, information that are necessary to provide to the locating system in a configuration step and information (or measures) that a WLAN terminal or the network itself must
30 provide to the system every time locating a terminal is required.

Information in the first category, that can be used

individually or in combination, are:

- location of Access Points, namely coordinates, with respect to a known reference, of the points in which Access Points or their antennas are arranged in case they are not
5 integrated in the apparatus, but connected thereto through a transmission line;

- radio-electric network characteristics, such as for example powers radiated by different Access Points, antenna radiation diagrams, the directions of maximum radiation of
10 the antenna, cables attenuations in case of external antennas, used frequencies, etc.;

- environmental characteristics, both in terms of arrangement of (perimetral and internal) walls, doors, windows, etc. and in terms of their electromagnetic
15 characteristics, such as attenuation coefficients, reflection, etc.;

- signatures, namely the map of values of received power or other measured radio-electric or performance parameters of the signal transmitted by Access Points, in predetermined
20 spatial positions belonging to the network coverage area.

It is to be noted that the collection of signatures requires an initial measuring operation that can also be very cumbersome. Signatures must be collected from a terminal,
25 such as a portable PC or a palmtop with WLAN apparatus, suitably realised or equipped with a specific software for collecting such measures and for transferring them to a related data base.

30 Information (or measures) in the second category, that can be used individually or in combination, are:

- the serving Access Point, namely the Access Point identification to which the WLAN terminal is connected (for

example MAC addresses);

- received Access Points, namely Access Point identifications received by the terminal;

- one or more radio-electric (such as, for example, power) or performance (such as, for example, BER or PER (Packet Error Rate)) parameters, measured on the signal received from WLAN terminal and transmitted from the serving Access Point;

- one or more radio-electric or performance parameters measured on all signals received from WLAN terminal and transmitted from received Access Points.

Figure 1 shows a typical example of WLAN network, marked with reference N. It comprises a plurality of Access Points, three of which are shown in the figure and designated by references AP1, AP2, AP3, each one equipped with an integrated antenna A or a remote antenna A'; in this latter case, antenna A' is connected to Access Point AP3 through cables or similar transmission lines L of a predetermined length.

In order to communicate with the Access Points, users use WLAN terminals T, such as, for example, PC or palmtops, equipped with a WLAN apparatus M, such as a PCMCIA card, a PCI adapter, etc. integrated or not in the terminal itself.

Communications (shown with a dashed line) occur through the radio medium with a standard protocol, such as, for example, one of IEEE 802.11 protocols, or a proprietary one.

Access Points APn are connected (solid line) to a wired network WN through which users access to all services available. A locating server S is present in the network and, activated by the user himself through required services or

the network, locates the terminal T.

Server S comprises or is coupled with a data base DB in which information entered during system configuration step are
5 stored, and a locating engine or module LM including different algorithms as program codes that can be executed on the server to perform the terminal position computation.

As said, the system needs an initial configuration step and
10 information that can be provided in this step are: Access Points location, radio-electric network characteristics, environmental characteristics and signatures.

These information, wholly or in part, are entered by system
15 users inside the data base DB. Various possible combinations are:

- AP positions;
- AP positions + network characteristics;
- AP positions + network characteristics + environmental
20 characteristics;
- signatures;
- AP positions + signatures;
- AP positions + network characteristics + signatures;
- AP positions + network characteristics + environmental
25 characteristics + signatures.

The system is able to operate with any one of the listed combinations.

30 Solutions are listed in order of amount of required time and investments for the configuration step: the first solution is the least heavy, the last one is the heaviest. Obviously, the heavier solutions allow obtaining greater locating

accuracies.

Every time a WLAN terminal must be located, the system requires it or the network about some information, that can
5 be: serving Access Point identification, received Access Points identifications, one or more radio-electric or performance parameters on the signal received by the WLAN terminal and transmitted from the serving Access Point, one or more radio-electric or performance parameters on signals
10 received from WLAN terminal and transmitted from received Access Points.

Not always will the terminal be able to provide all required information, but it will give the system any subsystem of
15 them. In particular, possible combinations are:

- server AP;
- server AP + received AP;
- server AP + measure of one or more parameters of server AP;
- 20 - server AP + measure of one or more parameters of server AP + received AP + measure of one or more parameters of received AP.

The system is able to operate with any one of the listed
25 combinations.

More complex terminals are able to provide the last combination, while simpler terminals will be limited to the first items of the list. Information that a terminal is able
30 to provide depend on the type of terminal, the type of used WLAN apparatus, and the operating system.

The locating accuracy will depend on the type of combination

provided to the system.

The locating engine or module LM organises information that it has available in a matrix form, as shown in the table in
5 figure 2, in which the first line includes the necessary information for configuring the system, while the first column includes information provided to system by terminals.

Every matrix box corresponds to a determined procedure for
10 locating a network terminal.

Each procedure listed in the table corresponds to a foreseen locating accuracy and a weight index in terms of difficulty in providing information during configuration. The weight
15 index is computed through a weight function. Such function estimates the weight (or cost) of each configuration depending on one or more of the following characteristics: difficulty in finding information, necessary time for collecting information, level of detail of necessary
20 information and need for updating and maintaining information themselves.

The system, depending on user-required accuracy and depending on the WLAN terminal available to the user will advise about
25 the type of less burdensome configuration that allows obtaining the required accuracy.

In any case, if only a subset of configuration information should be available, the system will adapt itself thereto and
30 will provide the maximum possible degree of accuracy.

Each locating procedure, in addition to providing the estimated position, also returns an accuracy value of such

location. This value depends on the selected procedure, but also on network characteristics and type of available information (for example, on signatures density, if used).

5 Once having ended the initial system configuration step (advised by the system itself or predetermined), the locating procedure choice can occur in various ways:

1) Taking into account data provided when configuring and
10 the type of measures provided by terminal or network, the system chooses the procedure that on average provides a greater accuracy, independently from the specific measure. In the table this means choosing a procedure belonging to the column on the side that is
15 most right as possible (according to available information after the configuring step) and the downmost line (depending on data provided by the terminal).

2) Selecting the procedure that corresponds to a better
20 computed accuracy. This selection is automatically performed by the system. Having a specific measure and configuration data available, possible procedures to be applied are known. A computed accuracy corresponds to each one of them, so that the system can choose the
25 procedure with best accuracy.

3) Selecting a procedure depending on accuracy and response speed of the service required by the user.
In fact, the services used by the user can be each
30 characterised by a minimum accuracy about user position, by a maximum response speed to service requests or both at the same time. For example, if the user requires a service for which it is important that the locating

system determines its position in the shortest possible time, independently from accuracy, the selected locating procedure will be such as to satisfy this request. If instead the user requires a service for which it is important to have an accuracy on the highest possible position, independently from the response times, the selected locating procedure will be such as to also satisfy this request. The procedure selected by the system will then be the one that allows satisfying both requirements posed by services required by users.

- 4) Selecting a procedure depending on tariffs applied to users.

In fact, each service used by a user can be priced differently depending on the accuracy with which, for service purposes, the locating system user position is determined. When a user decides to use these services, he can specify, in front of different pricing hypotheses, each corresponding to a given accuracy, the one he deems most adequate. The locating system will take into account this choice upon selecting the procedure with which a user is located.

- 5) It can be possible, for the locating system user, to choose a predetermined procedure. For example, having collected the signatures, it can happen that a modification of environmental characteristics (for example addition of a moving wall) can make a procedure requiring signatures unusable. In such case, for a transient period, the manager can decide to use other procedures, for example those based on the a priori knowledge of the Access Point position.

Upon entering a WLAN terminal in the network or immediately after the first location, it is further possible for the system to transfer on the WLAN terminal the algorithm contained in the locating engine. In this way it is the WLAN terminal itself that determines its own position and transfers it to the system upon every service request.

The advantages of this solution are:

- saving of network transmission capacity, since the terminal must not transmit measures to centralised server;
- higher accuracy in estimating the position with the same system response speed, since the necessary measures for determining the position can be performed by the WLAN continuously and not only upon every service request;
- possible simultaneous management by the server of a higher number of terminals since part of the processing load is performed by the terminals themselves or at least by those to which the system transfers the locating engine.

Moreover, the system, in order to save further transmission capacity and in order to be able to efficiently operate also with terminals equipped with less memory and processing capability, can transfer to the WLAN terminal only some or even a single locating procedure, chosen depending on measures that the terminal itself is able to perform and/or depending on the required service accuracy and/or depending on tariffs applied to a user.

With reference to such situation, in the initial step, it is necessary to transfer to the terminal the portion of data base DB used by the transferred procedures. Alternatively, it is possible to transfer only a suitable synthesis of the data base portion. For example, in case of signatures, it is

possible to transfer a statistical model of them.

Conveniently, the system can include a second data base in which the behaviour in time of the position of every user is recorded. By suitably extrapolating these information, it is possible to provide, with high accuracy, future positions of a WLAN terminal. These information are used both by the different procedures to reduce errors on position computation or to remove possible ambiguities, and to reduce the number of measures performed by the terminal and therefore to save network transmission capacity, and still more to provide the user with some services without any explicit request by the user himself.

The locating procedures provided by the method and system of the invention, with reference to the table in figure 2, are as follows.

Procedure 1

With geometric considerations only, it is possible to locate, starting from the position of all Access Points, the area covered by each one of them and therefore in particular the area covered by the one serving the terminal to be located. For example, point X is covered by the i-th Access Point if the distance from point X to such Access Point is less than the distance from the same point to all other Access Points.

Once having located the area in which the terminal can be found (or an estimation that the terminal is in there), an estimation of the barycenter position of such area is returned and, as uncertainty value, a meaningful dimension of such area, such as the maximum value or a suitable percentile

value, for example percentile 67%, of the distances between such barycenter and all points of the area.

Procedure 2

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By applying procedure 1 the area covered by the Access Point that serves the terminal to be located is pointed out. In addition, with topologic considerations, namely depending on the position of received Access Points with respect to the serving Access Point, it is possible to restrict the located
10 area into a sub-area. The barycenter of such sub-area is returned as position estimation, and as uncertainty value a meaningful sub-area dimension, such as the maximum value or a suitable percentile value, for example percentile 67%, of the
15 distances between such barycenter and all points of the sub-area.

For example, if received Access Point are those that can be found on the same side of the serving Access Point, the area
20 is restricted including only that part whose points are nearer to the received Access Points than the unreceived ones.

Figure 3 shows an example of a network composed of three
25 Access Points, respectively AP1, AP2, AP3. In it, the rectangles schematically show the coverage areas of each Access Point, namely the area in which every Access Point is server. Such areas are located through procedure 1. It can be assumed that from the performed measure it is obtained that
30 Access Point AP1 is, for a user, the serving Access Point, that Access Point AP2 is unreceived, and that Access Point AP3 is received. From these previous considerations, it can be assumed that the terminal can be found in the pointed-out

sub-area.

Procedure 3

- 5 By applying procedure 1 the area covered by the Access Point that serves the terminal to be located is pointed out. In addition, from measured parameter or parameters (for example power of signals transmitted by serving Access Point, received by terminal) the located area is restricted into a
- 10 sub-area. The barycenter of such sub-area is returned as position estimation and as uncertainty value a meaningful dimension of the sub-area is returned, such as the maximum value or a suitable percentile value, for example percentile 67%, of the distances between such barycenter and all points
- 15 of the sub-area.

The area located through Procedure 1 can be restricted since, for example, the received power depends on the distance between transmitter and receiver. As shown for example in

20 figure 4, if the terminal receives a high power, it means that it is near the Access Point (highlighted sub-area).

In general, for a given value of measured power, it is possible to delimit a circular crown or a related sub-area,

25 of a more complex shape. Alternatively to the power, any other measured parameter can be used that is function of the distance, such as for example signal/noise ratio, Bit Error Rate (BER), etc.

Procedure 4

Procedure 3 is applied and, taking into account for example the received power also from other Access Points, the sub-

area to which the terminal belongs is further restricted. The barycenter of such sub-area is returned as position estimation and as uncertainty value a meaningful dimension of the sub-area is returned, such as the maximum value or a
5 suitable percentile value, for example percentile 67%, of the distances between such barycenter and all points of the sub-area.

Since the received power depends on the distance between
10 transmitter and receiver, the sub-area within which the terminal to be located can be found is nearer to the Access Points from which a greater power is received. Also in this case, as an alternative to power, any other measured parameter can be used that is function of the distance, such
15 as for example signal/noise ratio, Bit Error Rate (BER), etc.

Procedure 5

From the Access Points positions, and knowing network radio-
20 electric characteristics (transmission powers, antenna radiation diagrams, aiming directions, etc.) it is possible to locate, with a higher accuracy with respect to procedure 1, the area covered by each Access Point, and then in particular the area covered by the one serving the terminal
25 to be located. The barycenter of such area is returned as position estimation and as uncertainty value a meaningful dimension of the area is returned, such as the maximum value or a suitable percentile value, for example percentile 67%, of the distances between such barycenter and all points of
30 the area.

For example, if the received power is used as reference parameter, point X is covered by the i-th Access Point if in

point X the received power of signals transmitted by the i-th Access Point is greater than the received powers of signals transmitted by all other Access Points.

- 5 The computation of power received in point X from each Access Point is performed according to one of the propagations models known in literature for indoor environments.

Procedure 6

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By applying procedure 5, the area covered by the Access Point that serves the terminal to be located is pointed out. In addition, with topologic considerations, namely depending on the position of received Access Points with respect to the
15 serving Access Point, the located area is restricted into a sub-area. The barycenter of such sub-area is returned as position estimation, and as uncertainty value a meaningful sub-area dimension, such as the maximum value or a suitable percentile value, for example percentile 67%, of the
20 distances between such barycenter and all points of the sub-area.

For example, again with reference to figure 3 and to similar considerations to those included as comment in procedure 2,
25 if received Access Points are only those that can be found on the same side of the serving Access Point, the area is restricted including only that part whose points are nearer to received Access Points with respect to the unreceived ones.

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Procedure 7

By applying procedure 5 the area covered by the Access Point

that serves the terminal to be located is pointed out. In addition, from measured parameter or parameters (for example power of signals transmitted by serving Access Point, received by terminal) the located area is restricted into a sub-area. The barycenter of such sub-area is returned as position estimation and as uncertainty value a meaningful dimension of the sub-area is returned, such as the maximum value or a suitable percentile value, for example percentile 67%, of the distances between such barycenter and all points of the sub-area.

The area located through Procedure 5 can be restricted since, for example, the received power depends on the distance between transmitter and receiver. Again with reference to figure 4 and to similar considerations to those included as comment to procedure 3, for a given value of measured power, it is possible to delimit a circular crown or a related sub-area, of a more complex shape. If the terminal receives a high power, it means that it is near the Access Point (highlighted sub-area). Alternatively to the power, any other measured parameter can be used that is function of the distance, such as for example signal/noise ratio, Bit Error Rate (BER), etc.

Procedure 8

By applying procedure 5 the area covered by the Access Point that serves the terminal to be located is pointed out. In addition, from measured parameters (for example powers received by terminal of signals transmitted from serving Access Point and from received Access Points) the located area is restricted into a sub-area. The barycenter of such sub-area is returned as position estimation and as

uncertainty value a meaningful dimension of the sub-area is returned, such as the maximum value or a suitable percentile value, for example percentile 67%, of the distances between such barycenter and all points of the sub-area.

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With similar considerations to those included as comment to procedure 4, since the received power depends on the distance between transmitter and receiver, the sub-area inside which the terminal to be located can be found is nearer to the
10 Access Points from which a greater power is received. Also in this case, alternatively to the power, any other measured parameter can be used that is function of the distance, such as for example signal/noise ratio, Bit Error Rate (BER), etc.

15 Procedure 9

Procedure 5 can be refined knowing the environmental characteristics, both in terms of arrangement of (perimetral and internal) walls, doors, windows, etc., and in terms of
20 their electromagnetic characteristics, such as attenuation, reflection coefficients, etc.

These information allow obtaining, with better accuracy with respect to procedure 5, the area covered by each Access
25 Point, and therefore also the area covered by the Access Point that serves the terminal to be located.

The computation of power received in every point is performed by using one of the propagation models known in literature
30 for indoor environments, that take also into account attenuations and reflections produced by the environment and to which the signal is subjected.

Procedure 10

By applying procedure 9, the area covered by the Access Point that serves the terminal to be located is pointed out. In addition, with topologic considerations, namely depending on the position of received Access Points with respect to the serving Access Point, the located area is restricted into a sub-area. The barycenter of such sub-area is returned as position estimation, and as uncertainty value a meaningful sub-area dimension, such as the maximum value or a suitable percentile value, for example percentile 67%, of the distances between such barycenter and all points of the sub-area.

For example, again with reference to figure 3 and similar considerations to those included as comment of procedure 2, if received Access Points are only those that can be found on the same side of the serving Access Point, the area is restricted including only that part whose points are nearer to received Access Points with respect to the unreceived ones.

Procedure 11

By applying procedure 9 the area covered by the Access Point that serves the terminal to be located is pointed out. In addition, from measured parameter or parameters (for example power of signals transmitted by serving Access Point, received by terminal) the located area is restricted into a sub-area. The barycenter of such sub-area is returned as position estimation and as uncertainty value a meaningful dimension of the sub-area is returned, such as the maximum value or a suitable percentile value, for example percentile

67%, of the distances between such barycenter and all points of the sub-area.

The area located through Procedure 9 can be restricted since, for example, the received power depends on the distance between transmitter and receiver. Again with reference to figure 4 and to similar considerations to those included as comment of procedure 3, for a given value of measured power, it is possible to delimit a circular crown or a related sub-area, of a more complex shape. If the terminal receives a high power, this means that it can be found near the Access Point (highlighted sub-area). Alternatively to the power, any other measured parameter can be used that is function of the distance, such as for example signal/noise ratio, Bit Error Rate (BER), etc.

Procedure 12

By applying procedure 9 the area covered by the Access Point that serves the terminal to be located is pointed out. From measured parameters (for example powers received by terminal of signals transmitted from serving Access Point and from received Access Points) the located area is restricted into a sub-area. The barycenter of such sub-area is returned as position estimation and as uncertainty value a meaningful dimension of the sub-area is returned, such as the maximum value or a suitable percentile value, for example percentile 67%, of the distances between such barycenter and all points of the sub-area.

30

With similar considerations to those included as comment to procedure 4, since the received power depends on the distance between transmitter and receiver, the sub-area inside which

the terminal to be located can be found is nearer to the Access Points from which a greater power is received. Also in this case, alternatively to the power, any other measured parameter can be used that is function of the distance, such as for example signal/noise ratio, Bit Error Rate (BER), etc.

Procedures 13-24

For these procedures, the method disclosed in WO-A-02-054813 can be employed.

Procedures 25-28

The method disclosed in WO-A-02-054813 can be further refined depending on environment physical and electromagnetic characteristics.

The statistic model disclosed in WO-A-02-054813 can be refined, in addition to the knowledge of the positions and electric characteristics of the Access Points, as already disclosed in WO-A-02-054813, also with the environmental knowledge. If, for example, the model refinement is performed by computing the received power in any point through any propagation model, the knowledge of environmental characteristics allows a higher computation accuracy, as already pointed out in Procedure 9.

Obviously, observing the invention principle, its embodiments and realisation parts can be widely changed with respect to what has been described and shown merely as a non-limiting example, without departing from the scope of the present invention, as defined by the enclosed Claims.